COAL-MINE HAZARDS FROM OVERLYING GASOLINE PIPELINES: DESCRIPTION OF GASOLINE EXPLOSIONS IN TWO PENNSYLVANIA BITUMINOUS-COAL MINES

BY W. D. WALKER, JR., AND J. H. DUMIRE

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INTRODUCTION

All pipelines used to transport liquid fuels over coal mines are potentially hazardous; however, this publication deals only with dangers in transporting gasoline. Since transporting gasoline by this method is an established practice, the hazards connected therewith should be recognized by coal-mine operators and pipeline companies so that every known precaution may be used to reduce and keep the hazards to a minimum.

The purpose of this paper is to direct the attention of coal-mine operators and employees, pipeline-company officials, and other interested persons to the explosion and fire hazards that arise from seepage of gasoline into underground mines. A hazard is not only presented in an individual mine when gasoline enters underground workings; but, in cases where mines are interconnected, a hazard exists in each such mine.

Once gasoline has entered mine workings, it is extremely difficult to remove, and to date no practicable method has been devised. Furthermore, it is nearly impossible to determine whether a mine into which gasoline has seeped can ever be safely operated thereafter. Even though tests do not indicate the presence of gasoline, there is no assurance that it will not be carried from abandoned areas where it has formed into pools into active workings during a heavy rainfall.

The following incidents occurred within a period of 5 days in February 1953. In each instance gasoline leaked from a pipeline into a small underground coal mine in Pennsylvania. In both mines the gasoline vapor was ignited, and persons were burned.

EXPLOSION OF GASOLINE IN MINE A

An explosion occurred Friday, February 20, 1953, in mine A, a small bituminous house-coal mine on a farm in Pennsylvania. The mine owner was in the mine when the explosion occurred and was severely burned about the face, neck, chest, and hands. The Federal Bureau of Mines was notified of the explosion through a telephone call from a neighbor of the mine owner on Tuesday, February 24, 1953, the Bureau in turn notified a State mine inspector, and an investigation was made the same day by two Federal coal-mine inspectors and the State inspector. A subsequent investigation was made March 18, 1953, by two Federal coal-mine inspectors.

The mine was opened into an abandoned mine in the Pittsburgh coal bed, and the one working face was about 300 feet from the portal. Ventilation was by natural means, and 3,500 to 5,000 cubic feet of air a minute was coursing through the passageways; the air was not controlled in any way, and the flow was not constant. A 6-inch gasoline line crossed the farm property about 230 feet from the nearest active mine workings. The mine owner, the only person working in the mine, mined the coal with a pick and carried it from the mine in buckets as needed for his home.

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It was determined from questioning the mine owner's sister that on the day of the explosion the owner, using a carbide lamp for illumination, had entered the mine, obtained two buckets of coal, and returned to the surface. Shortly thereafter, the sister entered the mine, using a flashlight for illumination, filled two buckets with coal, and brought them to the surface. The owner again entered the mine a short time later to get more coal. The sister was standing near the portal when she heard a blast and black smoke emitted from the portal. She ran to the portal, called to her brother, and then saw him staggering toward her. She ran into the mine, assisted him to the surface and to their home a short distance away, and because he was severely burned obtained help from a neighbor in getting him to a doctor and to a hospital.

There was definitely a leak in the gasoline line, because gasoline could be smelled anywhere on the farm, and a crew of men from the pipeline company were searching for the leak at the time of the investigation. It was believed that gasoline from the leak in the pipeline may have entered the mine through underground streams of water that entered the mine by drippers in the roof and was ignited by the flame of the carbide lamp used by the mine owner for illumination. However, this theory could not be substantiated during the original investigation because gasoline could not be smelled in the mine and could not be tested in water that entered the mine through drippers in the roof, combustible gas was not detected with a permissible flame safety lamp, and a sample of the mine air when analyzed at the Bureau of Mines laboratory did not contain combustible gases.

When interviewed in the hospital, the injured man stated that something blew up in his face when he bent over to pick up some pieces of coal at a point about 150 feet inby the pit mouth. He said he did not know what happened, and that he did not notice anything unusual about the mine and had not smelled gasoline fumes. He stated that he had a head cold on the day of the explosion and for that reason may not have detected the gasoline odor.

A subsequent investigation of the underground mine and farm property was made by two Federal coal-mine inspectors on Wednesday, March 18, 1953. This investigation was made following a rainy period, and the odor of gasoline could be detected throughout the mine. Tests with a permissible combustible-gas indicator revealed that explosive concentrations of gasoline vapors were present throughout the mine, ranging from close to the floor to 3-1/2 feet above the floor. Two samples of the mine air were collected during this investigation, and both contained gasoline vapors in explosive quantities.

The inspectors contacted workmen from the pipeline company who were on the property searching for another leak. These men showed the inspectors where they had dug holes along the pipeline where it crossed the property and where they had uncovered 300 to 400 feet of the line. Metal patches had been welded over holes in the line at two places, and a metal patch was being held in place with a clamp at another point. Pipeline-company employees informed the inspectors that, during the time they were searching for leaks, tests indicated that highest concentrations of gasoline vapors were found during or immediately following a rain along what had been the highwall of a strip-mining pit that had been backfilled. The mine had been stripped to within a few hundred feet of the mine portal, and surface subsidence indicated that there were connections between the house-coal mine and the backfilled strip pit through worked-out areas of an abandoned mine. Because of the connections between the mine and strip pit, the inspectors concluded that it was possible for gasoline from leaks in the pipeline to be carried during rainy periods through and around the abandoned mine workings and into the active mine.

Inasmuch as there was definitely a leak in the surface gasoline pipeline, gasoline from the leak could enter the mine, and explosive gasoline-air mixtures were detected in the mine, the inspectors concluded that the explosion was caused by the ignition of gasoline vapor with the flame of a carbide lamp used by the mine owner for illumination.

A sketch of the house-coal mine, showing details of the explosion, is shown in figure 1. The analytical results of air samples collected during the investigations are shown in table 1.

TABLE 1. - Results of analyses of air samples collected in mine A February 24 and March 18, 1953

Bottle No.	Date	Time	Location in mine	Percent				
				Carbon dioxide	Oxygen	Methane	Nitrogen	Hydrocarbons
J-693	2/24/53	1:45 p.m.	Innermost working place in mine	0.07	20.87	0	79.06	0
420-I	3/18/53	1:45 p.m.	At face of third entry	.40	19.60	0	77.80	[1]2.20
419-I	3/18/53	2:00 p.m.	About 30 feet inby mine portal entry	.30	19.40	0	78.10	[1]2.20

[1] Approximate composition of butane (C_4H_{10}).

Ingress to the mine during the second investigation was difficult and hazardous because of roof falls, and further investigations were not made. However, it is known that operations in the mine were never resumed.

EXPLOSION OF GASOLINE IN MINE B

Introduction

Gasoline from a leak in a products pipeline entered mine B, a small Pennsylvania bituminous-coal mine, and gasoline vapors were ignited by a spark from a mining machine that was being trammed along the main haulage road about 5:30 p.m., Wednesday, February 25, 1953. Two men operating the mining machine were the only men in the mine at the time of the explosion; both were burned but neither seriously. The flame was confined to the immediate area and burned only momentarily. Both men went to the surface without assistance.

The Bureau of Mines first learned of the explosion from a news item that appeared in a Pittsburgh newspaper on Sunday, March 1, 1953, and an investigation was made by three Federal coal-mine inspectors on Monday, March 2, 1953.

Mining Methods, Conditions, and Equipment

Mine B was opened into the Pittsburgh coal bed by four drifts. The coal bed averaged about 74 inches in thickness in the area worked. Twenty-one men were employed, 5 on the surface and 16 underground, and produced about 100 tons of coal a day, loaded by hand and with a mobile loading machine. A room-and-pillar method of mining was followed, and mining was confined to partial recovery of chain and barrier pillars.

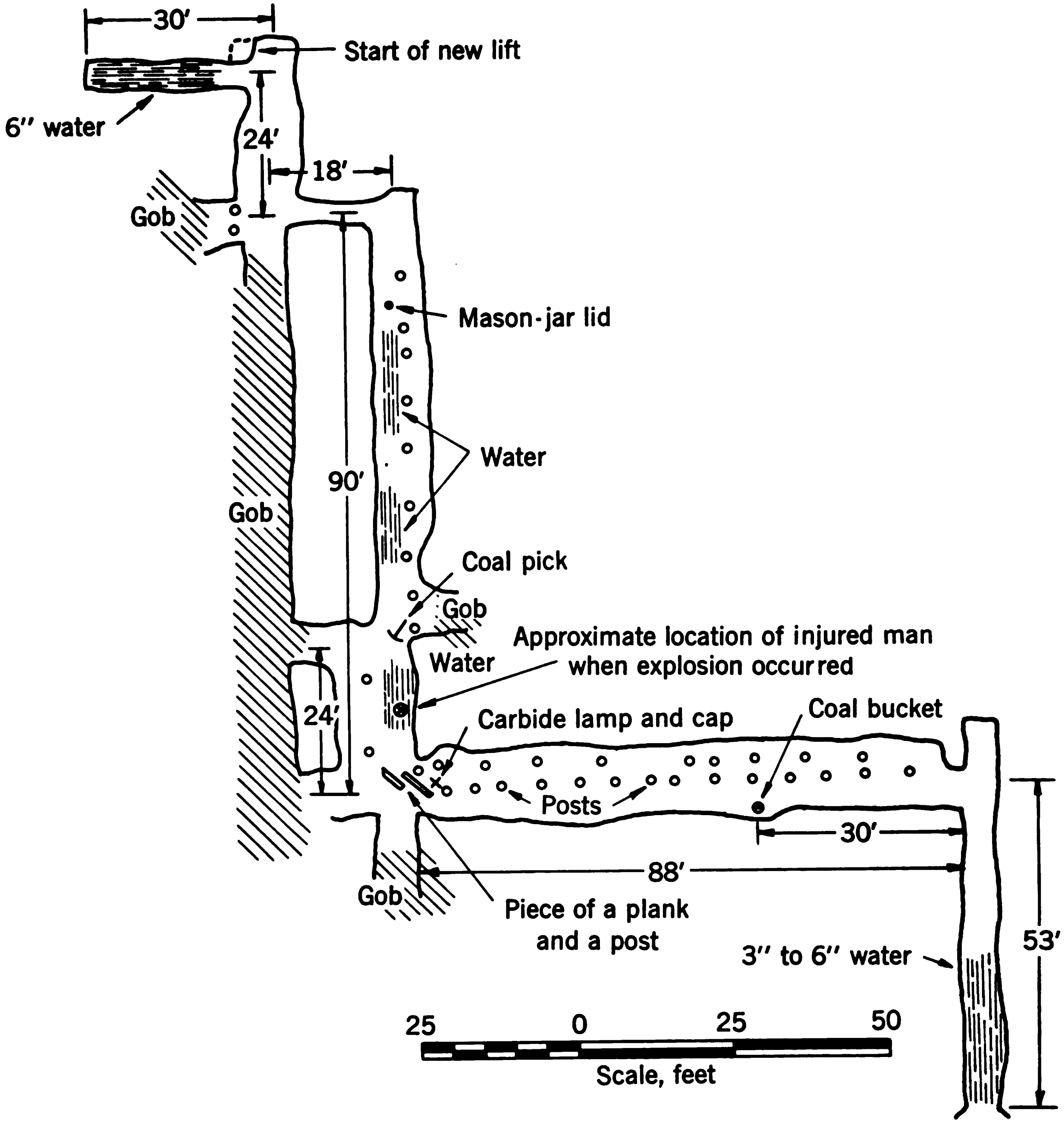

Figure 1. - Sketch of house-coal mine, mine A.

The mine was wet throughout and was not rock-dusted.

The mine was classed nongassy; air samples had been collected during each of 8 Federal mine inspections, and methane (0.04 percent) was contained in only 1 sample. Although an axial-flow fan was installed on the surface, ventilation at the time of the last previous Federal inspection, completed February 3, 1953, and at the time the explosion occurred (February 25, 1953) was by natural means. The fan was started about 10:45 a.m., February 28, 1953, and was operated blowing when a Federal investigation was made March 2, 1953. Preshift, onshift, and weekly examinations for gas were made, and records of these examinations were kept on the surface.

Electric power, at 275 volts direct current, was generated on the surface by a motor-generator set. Trolley and feeder wires were installed on insulated hangers and provided with cutout switches at suitable intervals. Permissible and nonpermissible electric face equipment was used. Only one rail of the main haulage track was bonded, and many of these bonds were defective.

Permissible electric cap lamps were used for portable illumination, and smoking was not permitted underground.

Story of Explosion

A 6-inch gasoline pipeline was constructed over the mine about 1930. The pipeline was pumping gasoline on Wednesday, February 25, 1953. The location of the pipeline was not shown on mine maps in the mine office. Pressure in the line was 500 or 830 pounds per square inch, according to the direction of flow, and gasoline was being pumped at a pressure of 830 pounds per square inch on Wednesday, February 25, 1953. The pipeline was patrolled by airplane once every 10 days, and foot patrols were made twice weekly. Foot patrols were not made on Wednesdays.

About 2:30 p.m., Wednesday, February 25, 1953, a leak was discovered in the gasoline line over the mine by an employee of the Bell Telephone Co. of Pennsylvania while patrolling that company's telephone circuits. The leak was reported to the pipeline-company office in Greensburg, Pa., and was temporarily repaired about 5:00 p.m., Wednesday, February 25, 1953. The leak was said to have been small and was repaired with a rubber plug held in place with a metal patch and clamp. Officials of the mine were not informed of the leak and were unaware that one had occurred. The surface where the leak occurred had settled several years ago, and the pipeline company officials did not know that there was an active mine under the pipeline at that point. The time the leak actually occurred and the amount of gasoline that escaped from the line could not be determined. Pillars had been recovered in the area under the leak, and the surface was broken at that point. Generally, mining in the area under the line had been completed before the line was installed, but some pillars had been partly recovered in 1951 and 1952 near where the leak occurred. Cover over the coal bed near the leak in the line ranged from 40 to 50 feet in thickness, according to mine officials.

Mine B produced coal one shift a day, and coal was cut on the second shift. The mine worked Wednesday, February 25, 1953, and the two machinemen entered the mine about 2:30 p.m. They smelled gasoline when they reached the 2 right working section, the farthest inby working section, about 2:50 p.m. The men did not recognize the danger indicated by the gasoline fumes and continued into the 2 right section. They cut two places in the 2 right section with a permissible shortwall mining machine and started tramming the machine along the main haulage road to the 1 left working section. The men again smelled gasoline fumes along the haulage road; they had traveled about 300 feet outby 2 right when the explosion occurred about 5:30 p.m. These men said that a black puff came up from the floor and then heat hit them. The flame burned out almost immediately; both men were burned but neither seriously. They immediately went to the surface and reported the explosion to mine officials.

Power was cut off the mine about 6:00 p.m., and the mine superintendent and the machinemen entered the mine about 6:15 p.m. They arrived at the place where the explosion occurred about 6:30 p.m. The superintendent made an examination with a permissible flame safety lamp at the roof and did not detect explosive gas, but he did smell gasoline and saw gasoline on the water coming out of the gob on the left side of the haulage road. A "Danger" sign was placed at the portal about 8:30 p.m.

The mine foreman left the 2 right working section about 2:15 p.m., and three other employees left the 2 right section about 2:45 p.m. and traveled along the haulage road to the surface. The men did not smell gasoline fumes along the haulage road, but they had been using kerosine to clean some machine parts in the 2 right section and may not have been able to detect gasoline fumes if they were present.

Investigation of Cause of Explosion

Three Federal coal-mine inspectors made an investigation in the mine on Monday, March 2, 1953. Drift openings were provided at the outby and inby ends of the mine, and the underground investigation consisted of travel from the haulage portal along the haulage road to the openings at the inby end. Gasoline fumes were smelled along the main haulage road about 1,700 feet outby the point of ignition and throughout the inby portion of the haulage road. A sample of liquid was collected from a pool of water about 1,500 feet outby the point of ignition. Analysis of this sample in the Bureau of Mines laboratory at Bruceton, Pa.,indicated that the liquid was gasoline that was partly evaporated, which showed that the gasoline was being carried on the mine water. Tests for gasoline vapors were made with a permissible combustible-gas indicator near the floor along the haulage road, and explosive gasoline-air mixtures were detected at several places near the floor along the gob near the point of ignition. A sample of the mine atmosphere collected along the haulage road contained gasoline vapors when analyzed at the Bureau of Mines laboratory in Pittsburgh, Pa.

About 1,500 feet of the gasoline line had been uncovered on the surface and was examined by the investigators. The pipe was badly pitted near the point of the leak, and the pitted spots were being strengthened with metal patches welded to the pipe. The point of the leak had been repaired with a welded metal patch. A 2-inch water pipeline had been installed on the surface, and water with a detergent added was being put into the mine through a surface crack in an attempt to wash gasoline from the pillared area underground.

From information obtained by observation and from the two men involved in the explosion, company officials, and personnel of the pipeline company, the investigators concluded that a leak developed in a gasoline line over mine B sometime before 2:30 p.m., Wednesday, February 25, 1953, and was not repaired until about 5:00 p.m. the same day; an undetermined amount of gasoline entered through surface cracks into a pillared area adjacent to the haulage road of the mine, and gasoline was carried on the mine water to the haulage road and was ignited by a spark, probably between the rails and the wheels of the mining machine while it was being trammed along the haulage road.

Since the gasoline on the mine water in the mine constituted an imminent explosion hazard, the Federal inspectors on March 2, 1953, posted a notice at the mine debarring persons from entering the mine as provided for in Section 203(a)(1) of the Federal Coal Mine Safety Act.

A sketch of the inby portion of mine B showing the location of the leak in the pipeline over a pillared area and the location of the ignition of gasoline is shown in figure 2. Analyses of air samples collected during the investigation of the explosion are shown in table 2.

TABLE 2. - Results of analyses of air samples collected in mine B, March 2, 1953

Bottle No.	Date	Time	Location in mine	Percent					Air per minute, cubic feet
				Carbon dioxide	Oxygen	Methane	Nitrogen	Hydrocarbons	
E-3415	3/2/53	2:32 p.m.	Air at bottom of gob, along main haulage road, where gasoline fumes were entering the mine	0.17	20.64	0	79.11	[1] 0.08	
C-2190	3/2/53	2:50 p.m.	At main return-air drift opening	.08	20.77	0	79.15	0	16,000

[1] Approximately nonane (C_9H_{20}).

Examination for Hazards From Gasoline in a Mine Connected to Mine B

Two mines operated by the same coal company were connected to mine B. One was an active mine, and the other was idle except for pumping operations involving one man on each of three shifts daily. From information gathered from the engineering department of the coal company operating the mines on the contours and conditions in the area between the active mine and mine B, it was considered unlikely that the gasoline in mine B would affect the active mine. However, the inactive mine was lower than mine B, some water from mine B was known to be draining into the inactive mine, and the potential hazard of gasoline being carried on the water into the inactive mine was discussed with officials of the coal company. These officials were aware of the hazard and were making regular checks in the inactive mine.

To get a clearer picture of the situation, an investigation was made March 12, 1953, in mine B and the inactive mine. Gasoline vapor was detected at several places in mine B, and gasoline could be seen on the water coming from the gob under the leak in the surface gasoline line. Although most of the water discharged at a drift portal of mine B, some of the water did flow in the direction of the inactive mine. The water surface at the central sump in the inactive mine was examined, and evidence of gasoline was not found. Indications of gasoline were also not found during examinations made along the water course in the direction of mine B, and a sample of return air in the inactive mine did not contain gasoline vapor.

About 3 miles of worked-out area separated mine B and the inactive mine, and examinations could not be made to the extent that true conditions could be

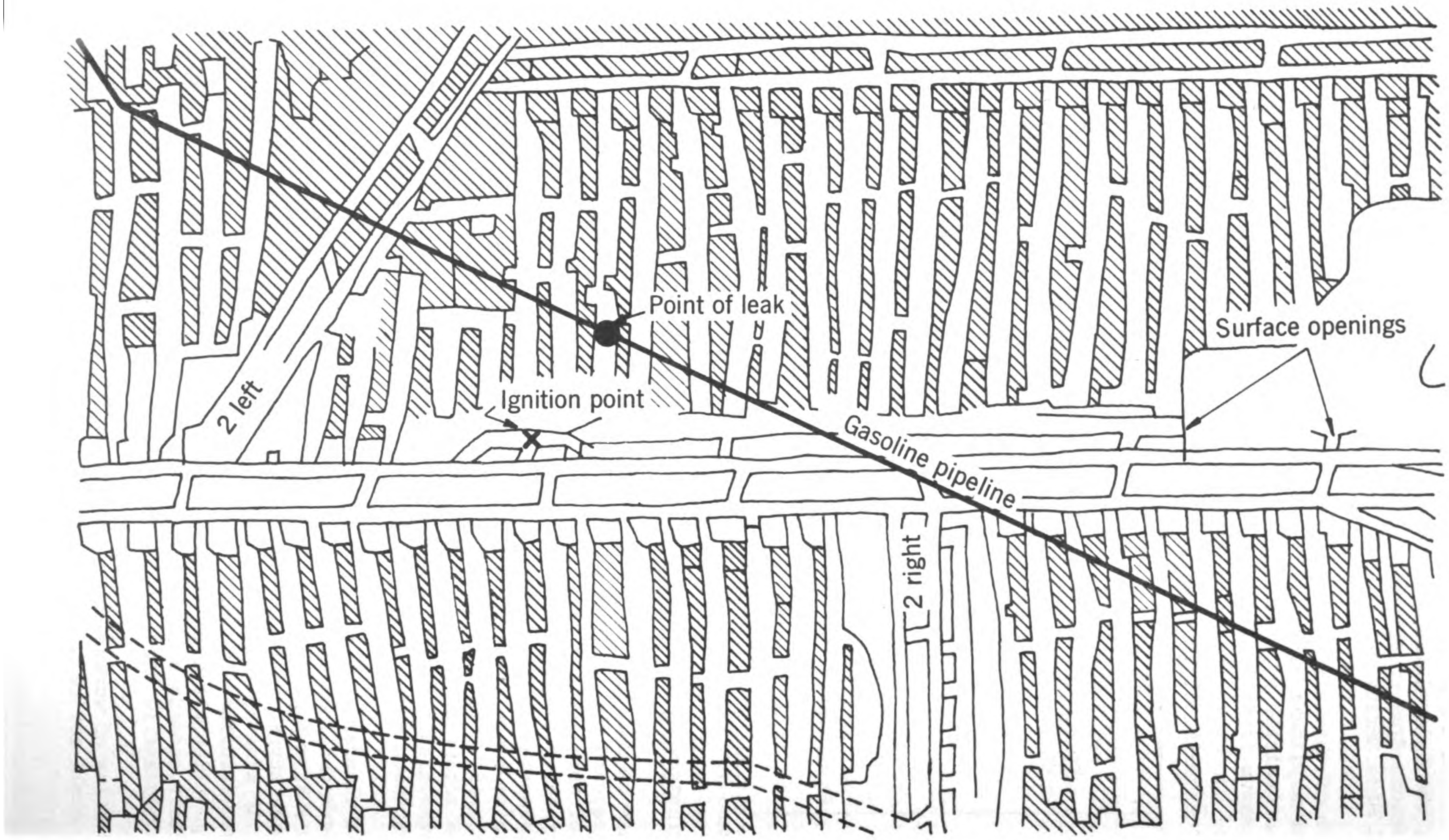

Figure 2. - Sketch of mine B.

determined. Hazards from gasoline were not present in the inactive mine when the investigation was made. However, the Federal inspectors informed officials of the coal company that a potential hazard must be considered to exist because water was known to be flowing from mine B toward the inactive mine. The officials were advised to keep a careful check to guard against the possibility that gasoline might enter the mine and be ignited by electrical installations at the mine sump or by an electric locomotive operated by the pumpers on the haulage road along the water course from mine B. The inspectors also informed the company officials that the potential hazard must be considered to be greater at times when the volume of water flowing from mine B to the inactive mine increased by reason of heavy rainfall.

Rain as a Factor in the Fire and Explosion Hazards

After the gasoline was ignited in mine B and a closing order was posted by the Bureau of Mines, the mine was never again reopened as a producing mine. However, the mine continued to be ventilated, and regular examinations were made by mine officials. The Bureau of Mines continued to keep in close contact with officials of the company.

One bit of information disclosed by company officials serves to illustrate the long-range hazard involved when gasoline enters an inaccessible abandoned area of an underground mine. The officials found that in a relatively short time after the investigation by Bureau of Mines personnel the mine was almost free of gasoline vapor, but following a heavy rain gasoline was carried out of the pillared area by the mine water to the extent that concentrations of gasoline vapors were greater than immediately after the explosion occurred. Rains over a period of several weeks continued to result in high concentrations of gasoline fumes in the mine.

Inasmuch as conditions in the pillared area in mine B could not be determined, certain reasonable assumptions must be drawn to explain the recurrence of high concentrations of gasoline vapors in open workings of the mine during rainy periods. Gasoline would tend to pool in low areas of the abandoned workings. Since gasoline is considerably lighter than water (specific gravity about 0.7) and will float on water, it was carried on water that entered the pool areas during rainy periods and into open workings of the mine. Some of the gasoline was not washed from the area during the first rainy period and remained to be carried into open workings during the next such period.

Removal of Equipment From Mine B

On August 6, 1953, the operator of mine B appealed to the Director of the Bureau of Mines for temporary relief from the withdrawal order issued pursuant to the provisions of Section 203(a)(1) of the Federal Coal Mine Safety Act on March 2, 1953, by three Federal mine inspectors, to permit recovery of mining machinery and equipment before sealing the mine. The operator indicated that the material was to be removed by animal power and a winch. On August 12, 1953, an investigation was made at the request of the Director by three Federal inspectors to determine if conditions in the mine were such that the equipment could be recovered safely. Following the investigation, the investigating committee informed the Director that hazards did not exist at the time of the investigation but that conditions in the gob area could not be determined and that conditions were subject to change when heavy rainfall caused an increased volume of water to enter the area where gasoline entered the mine, creating a potential explosion hazard affecting the entire mine.

On August 12, 1953, the Director of the Bureau of Mines informed the operator of mine B that relief from the withdrawal order was being granted to permit removal of equipment from the mine under the following conditions:

(1) That the period of time granted to remove the equipment should not exceed 30 calendar days.

(2) That a Federal coal-mine inspector be present at all times while equipment is being removed.

(3) That no igniting agents should be permitted in the mine.

(4) That electric power should not be conducted into the mine.

Work of removing equipment from the mine was begun August 17, 1953. Before each working shift, the mine was examined by the Federal inspector and a company official. The examinations included tests by the Federal inspector for gasoline vapor with a permissible combustible-gas indicator. Hazards from gasoline were not encountered during removal of equipment. All equipment was removed by September 3, 1953, and the area of the mine affected by the gasoline was isolated with incombustible stoppings.

Samples of the mine air were collected near the floor along gob areas in mine B during the time equipment was being removed. The analyses of these samples are shown in table 3. Although the concentrations of gasoline vapor in these samples were well below dangerous amounts, it is significant to note that about 6 months after gasoline entered the mine, gasoline vapor was still present.

TABLE 3. - Results of analyses of air samples collected during removal of equipment from mine B, August 17, 18, 21, and 25 and September 3, 1953

Bottle No.	Date	Time	Location in mine	Percent				
				Carbon dioxide	Oxygen	Methane	Nitrogen	Hydrocarbons
H-840	8/17/53	11:40 a.m.	250 feet outby 2 right along main entry	0.30	20.35	0	79.30	0.05
H-5921	8/18/53	8:45 a.m.	150 feet outby 2 right along main entry	.13	20.62	0	79.25	0
H-5927	8/21/53	8:27 a.m.	200 feet outby 2 right along main entry	.46	20.02	0	79.45	.07
G-4870	8/25/53	2:15 p.m.	Bottom of gob fall inby end of 2 left entry	1.66	16.52	0	81.79	.03
G-4782	9/3/53	8:05 a.m.	200 feet outby 2 right along the main heading	.37	20.36	0	79.20	.07

ELECTROLYSIS TESTS OF PIPELINE AT BOTH MINES

According to officials of the pipeline company, corrosion of their pipelines arises from four main causes: (1) Natural oxidation, (2) electrolysis, (3) chemical reaction of soils and water, and (4) chemical reaction caused by certain bacteria.

Since the leaks in the gasoline line at the house-coal mine and over mine B were in the same pipeline and resulted from pitted holes, such as are caused by electrolysis, tests for electric current on the pipeline were made at both locations by Bureau of Mines electrical engineers. Electric current was not found on the line over mine B, but the results of the tests could not be considered conclusive because they were made when the mine was shut down, with all underground power circuits deenergized. Since power was never put back on the mine circuits under the pipeline after the mine was closed, tests could not be made under conditions such as existed at the time the mine was in operation. The Bureau requested a section of the pipeline for laboratory tests for electrolysis, but since the pipeline company did not replace the defective pipe, such tests were not made. Surface subsidence, although present, was known not to be a factor because the leak in the line was a corroded hole rather than a break, but the exact cause of the leak was not positively determined. However, the pitted spots on the pipeline were concentrated at points over the mine where conditions for stray currents were favorable; therefore, electrolysis cannot be discounted as the cause of the leak. The line crossed over underground circuits in a mechanized working section of the mine and over a portion of the poorly bonded main haulage track, which was the grounded side of the 250-volt direct-current power circuit. The cover over the coal bed was shallow at these points, from 40 to 50 feet, and the pitted spots in the line were concentrated near the leak in the pipeline. At this point the pipeline crossed over circuits in the working section, and any stray currents on the line would have a tendency to leave the line and get on the mine track. Bureau of Mines electrical engineers considered conditions to be ideal for electrolysis with respect to the gasoline pipeline at the point where the leak occurred over mine B.

On March 23, 1953, tests for stray currents were made by a Bureau electrical engineer on the gasoline line where a leak had occurred near mine A. The pipeline at the test location had been uncovered, and pitted spots were being strengthened with metal patches. The instruments used in these tests were a milliammeter and millivoltmeter. Measurements of voltage and current were made between the pipeline and an electrode driven in the ground approximately 50 feet from the pipe on both sides and adjacent to the pipe and 50 feet in both directions from the test locations. According to a report on these tests, the momentary voltage and current readings were as follows: With the electrode placed 50 feet from the pipe toward the south, the maximum current indicated was 0.06 milliampere and the voltage 0.02. With the electrode placed 50 feet from the pipe toward the north, the maximum current indicated was 0.4 milliampere and the voltage 0.25. With the electrode placed beside the pipe and 50 feet from the test location toward the east, the maximum current indicated was 0.35 milliampere and the voltage 0.1. With the electrode placed beside the pipe and 50 feet from the test location toward the west, the maximum current indicated was 0.5 milliampere and the voltage 0.2. In all the above tests, the pipeline was found to be negative to the surrounding ground. Although the current and voltages fluctuated considerably, a reversal of polarity was not indicated in any of the tests.

The source of the currents indicated by these tests is unknown. In order to make this determination, an extensive study may be required. Tests conducted over a longer period of time may or may not show a reversal of polarity.

The pipeline was covered up again soon after the above-mentioned tests were made, and additional tests were never made. Although the source of the stray currents was not definitely established, it is interesting to note that, although electricity was not used in the house-coal mine, an electric railway (streetcar line) was operated near the pipeline and could have been the source of the stray currents. Inasmuch as surface subsidence definitely was not the cause of the leak in the pipeline and the pipeline near the leak was found to be carrying stray currents, it is not unreasonable to suppose that the leak in the gasoline line that resulted in an explosion of gasoline vapors in the house-coal mine could have been caused by electrolytic action of stray currents on the line.

DISCUSSION OF HAZARDS TO UNDERGROUND MINES FROM GASOLINE LINES

From experiences in mine A and in mine B, with a study of some of the properties of gasoline, we can evaluate the hazards presented by gasoline lines to coal mines operated under the lines. Leaks can occur in gasoline lines over underground coal mines by reason of natural oxidation, electrolysis, chemical reaction of soils and water, chemical reaction of certain bacteria, and surface subsidence because of underground pillar recovery. Gasoline from such leaks can enter underground workings and spread throughout large areas of a mine. Also, should the gasoline pool in low areas of inaccessible abandoned workings where increased water flow, as during rainy seasons, may carry it into active workings, it would be impossible to determine when the mine was free of fire and explosion hazards from the gasoline.

If gasoline is exposed to air, the gasoline vaporizes and mingles with the air in proportions according to the temperature of the air and the grade of gasoline; lighter gasolines will mingle with air in greater proportions than heavier products.[3] The explosive range of gasoline-air mixtures is from 1.4 to 6 percent of gasoline vapor. Although this range of explosibility is narrow as compared to other mixtures of combustible gases and air, it can readily be seen that a relatively small amount of gasoline vapor is necessary to render explosive a very large volume of air. According to Burrell,[4] if 1 gallon of gasoline is allowed to change into vapor simply by exposing it to air in a room, and if the room is gastight, the 1 gallon of gasoline can render explosive 2,100 cubic feet of air, the amount contained in a room measuring 21 by 10 by 10 feet. Considering that enormous amounts of gasoline can enter underground mines from leaks in surface gasoline lines, we get some idea of the tremendous fire and explosion hazards involved.

Gasoline vapor is about three times as heavy as air and would therefore be found near the floor. This property of gasoline vapor in itself could be hazardous to mines, inasmuch as mine personnel are accustomed to dealing with combustible gases (mainly methane) with specific gravities of less than 1 and making tests near the roof. It was the natural inclination of the mine superintendent of mine B to test for explosive gas near the roof when he entered the mine following the ignition of gasoline; it did not occur to him at the time that explosive gasoline-air mixtures might be present near the floor. It is highly possible that dangerous gasoline-air mixtures could exist in a mine and not be detected because tests would not be made near the floor.

DETECTING GASOLINE VAPOR

Gas-testing devices used in mines, including permissible flame safety lamps, while safe to use in gasoline-air mixtures, are not accurate when used in such mixtures. Flame safety lamps will give evidence of the presence of an explosive mixture and satisfactory percentages of approximately half the lower explosive limit. Below this limit the lamps decrease in value as detectors, and at 0.3 percent and lower the evidence is so small and difficult to observe that it should not be depended upon.[5]

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[3] Burrell, G. A., Hazards in Handling Gasoline, Bureau of Mines Tech. Paper 127, 1915, 12 pp.

[4] See footnote 3.

The permissible electric methane testers (E-2 and W-8) used in mines can be used to detect percentages of gasoline-air mixtures, but, since the instruments as approved are calibrated to indicate the percentages of methane, a recalibration would have to be made to be entirely accurate for other gases. In lieu of recalibration, the following formula can be used for practical purposes to compute the percentage of any combustible gas present when tested with an E-2 or W-8 methane indicator:

$$\frac{\text{Reading on dial of E-2 or W-8}}{\text{Lower explosive limit of methane}} \times \text{Lower explosive limit of gas tested}$$

$$= \text{Percent of combustible gas present}$$

Using the above formula, if tests with an E-2 or W-8 methane indicator in a gasoline-air mixture resulted in a reading on the dial of 1 percent, by substituting in the formula we get the following results:

$\frac{\text{1 percent}}{\text{5 percent}} \times 1.4$ percent = 0.28 percent of gasoline vapor present. This method will give a reasonably satisfactory indication of the explosion hazard presented by a gasoline-air mixture, but a positive determination of the amount of gasoline present in air can only be made with an instrument calibrated for gasoline vapor or by chemical analysis.

Very small concentrations of gasoline can be detected by sense of smell. Experiments carried out by the Bureau of Mines have shown that the odor of gasoline is noticeable in inhaled air at a concentration of 0.03 percent.[6] The investigators in mine B found that they could detect gasoline vapor by smell long before any indication was registered on a testing instrument. The men involved in the ignition of gasoline in mine B smelled gasoline before the explosion. The odor did not indicate danger to them, and the gasoline was ignited and could have been disasterous.

CONCLUSIONS

It is recognized that pipelines are important for the economical transportation of gasoline from refineries in quantities necessary to satisfy our present-day demands.

Hazards to coal mines under gasoline lines are primarily hazards to the lives of underground mine personnel. Economic hazards to such mines are also involved because of possible damage to mine properties from leaks in the lines. It is also significant to note that gasoline entering one mine may present a hazard to adjoining mines.

In the two instances known to the Bureau of Mines where gasoline entered underground mines, the gasoline was ignited, persons were injured, and the mines never agsin resumed production of coal. In the case of mine B, a disaster could have resulted, inasmuch as 14 men were employed underground during a coal-producing shift.

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[5] Hooker, A. B., Yant, W. P., and Zellers, D. H., Are Flame Safety Lamps Suitable for Detecting Petroleum Vapors? Bureau of Mines Inf. Circ. 6083, 1928, 6 pp.

[6] Fieldner, A. C., Katz, S. H., and Kinney, S. P., Gas Masks for Gases Met in Fighting Fires, Bureau of Mines Tech. Paper 248, 1921, 61 pp.

Coal mines operated under gasoline pipelines do represent a risk to operators of such lines. Leaks in the lines may be caused by electrolysis from stray electric current, corrosion, or from subsidence caused by the extraction of coal pillars. Such leaks result in loss of product, disruption of service to customers, and possible liability of the operator of the lines for property damage resulting from the leaks. These risks are primarily economical.

RECOMMENDATIONS

The following recommendations are offered relative to the safety of personnel of underground mines operated under gasoline pipelines:

1. An exchange of information should be made between mining companies and operators of gasoline lines.

2. The location of gasoline lines should be shown on mine maps.

3. A plan of mining under gasoline lines should be agreed on by the mining company and the pipeline company, and the plan should offer the greatest possible safety for underground mine personnel.

4. Mining companies should be notified immediately by pipeline companies of leaks in surface lines over mining property.

5. Every effort should be made to prevent or minimize the effects of electrolysis and corrosion on pipelines used to transport flammable liquids.

6. The underground officials of mines where potential hazards from gasoline seepage are present should be fully advised of the danger and instructed on methods of determining the presence of gasoline and the procedure to be followed in an emergency.

7. Since gasoline may enter some coal mines quickly and without warning, the odor of gasoline in a mine should be accepted as a danger signal, and steps should be taken immediately to protect mine personnel.